MODIS SCIENCE DATA SUPPORT TEAM PRESENTATION

June 21, 1991

AGENDA

1. Action Items
2. MODIS Airborne Simulator
3. MODIS-T Instrument Meeting
4. Product Granule Sizes
5. Assumptions/Tracking List

ACTION ITEMS:

05/03/91 [Tom Goff and Team]: Document plans for Level-1A and Level-1B processing, and indicate what information will be included in each product. Include a list of assumptions, brief rationale, scenarios, and trade-offs. (An updated version was included in the handout on 06/14/91.) STATUS: Open. Due date 06/07/91

05/03/91 [Lloyd Carpenter]: Prepare a Level-1 processing assumptions, questions and issues list, to be distributed to the Science Team Members and the MCST for comment. (An executive summary and an updated list are included in the handout.) STATUS: Open. Due date 06/07/91.

05/31/91 [Liam Gumley]: Talk with Mike King as soon as he returns about what he wants and what he needs from the SDST as far as MAS processing is concerned. (Liam met with Mike. A report was included in the 06/14/91 SDST handout.) STATUS: Closed. Due date 06/21/91

06/07/91 [Liam Gumley]: Speak to Alfredo Huete and Alan Strahler regarding their MAS requirements. (A report of the discussions is included in the handout.) STATUS: Open. Due date 06/21/91

06/07/91 [Liam Gumley]: Gather information on the need for MAS Level-1B browse data from the prospective MAS data users. (A report is included in the handout.) STATUS: Open. Due Date 06/21/91

05/31/91 [Al McKay and Phil Ardanuy]: Examine the effects of MODIS data product granule size on Level-1 processing, reprocessing, archival, distribution, etc. (A preliminary report is included in the handout.) STATUS: Open. Due Date 06/21/91

ACTION ITEMS FROM SDST MEETING 06/14/91 [Liam Gumley]

(1) Talk to Mike King about his requirements for MAS processing.

I met with Mike King at GSFC and heard his views on how the MAS processing should proceed. He believed that the SDST should be involved in processing MAS data to a "Level-1B" stage, where the data would consist of calibrated and geolocated radiances. There is a Level-1A processing stage which is done at Ames. This involves the conversion of the ER-2 aircraft data (Level-0) to an intermediate format which contains digital instrument counts, black body thermistor counts, time, aircraft position etc.

Since the MAS will evolve with time, the Level-1B processing should accommodate changes such as

- varying total number of instrument channels (up to 50),
- varying number of digitization levels for each channel (8 to 12 bits),
- different spectral bands,
- different spectral bands assigned to different instrument channels.

In order to obtain more than 8 bits in a given channel, it may be necessary to use another channel as storage space for the extra bits. It is also important to note that changes to the MAS may make it possible for some of the cases mentioned above to change DURING a flight mission. For example, it may be possible to install two sets of 50 spectral channels on the MAS, and switch between them during flight.

It is important to be able to quickly review all the data for a given flight mission, and this could be done by a browse facility available after Level-1B processing. A browse dataset generated during Level-1B processing could consist of a reduced spatial resolution image of each straight line flight track in a mission, along with a composite image of all the flight lines. The primary purpose would be to identify clouds, and ocean/land features of interest. Several spectral bands, depending on the MAS configuration, would be used. The browse facility would be a local interactive GSFC facility, with the option of producing hardcopy images for users external to GSFC.

There should be several mechanisms by which end users could obtain the Level-1B data. Internet links are desirable, along with standard media such as 9 track magnetic tape or Exabyte tape. It is important to allow end users to perform further processing on external systems.

(2) Talk to Ed Masuoka regarding LTP computing facilities.

Ed indicated that LTP facilities included a VAX cluster consisting of 11-780 and 8250 systems with 9 track and Exabyte tape drives, and an I^2S imaging system. There are also 2 Silicon Graphics IRIS workstations, and a number of Sun workstations.

All of these computers are linked and are accessible via Internet. Imaging software available on the workstations includes IDL, PCI, and LAS. A charging system applies to users of the LTP facilities where small projects (as determined by LTP) are charged $7K, large projects are charged $14K.

(3) Talk to Alfredo Huete and Alan Strahler about their requirements for MAS processing.

I called Alfredo Huete and outlined the status of planning for the MAS Level-1B processing. He said that he would review his plans for the MAS data in the next few weeks and get back to me if there were any points he would like us to take into consideration. Alan Strahler is away until the beginning of July.

(4) Investigate browse generation.

I talked to Chris Moeller at Wisconsin to determine his strategy for MAMS browse/quicklook. When a set of data is received for a flight, it consists of every 3rd line to avoid along track oversampling. Every 15th line of this subsampled data set is examined to determine data dropout regions, cloud, land/ocean. A typical MAMS flight mission generates around 20000 to 25000 lines of good image data, which may be spread over 7 to 10 straight line flight tracks (see following processing summary for data rate information). Thus a typical flight track is 2000 to 3000 lines long. This would correspond to a typical "scene". It is useful to look at all spectral bands to determine if any problems occurred with the digitizer or associated electronics.

A possible scenario for MAS Level-1B browse might then be to create browse imagery for each straight line flight track in a mission, and then to display these with existing imaging software on a Silicon Graphics IRIS. The user would be able to select the spectral band, flight track number, and mission. This facility would be available to users at GSFC, and would possibly be available to users with Internet links to GSFC. Hardcopy browse imagery could be generated for other users.

(5) Meeting with Paul Menzel and Mike King.

I met with Paul Menzel, Mike King, and Al Fleig at GSFC. Paul Menzel indicated his preparedness to contribute MAMS processing code for MAS calibration and navigation, and suggested that I visit Wisconsin soon to investigate and obtain the code and some MAMS test data. Paul would like to see this visit take place before the 20th of July. I called Chris Moeller at Wisconsin, and he thinks that the week of the 8th would be suitable. A three day visit is planned at present.

Mike confirmed that he would like to see a calibrated, navigated Level-1B product in an accessible format, with a browse facility available at GSFC using existing imaging software on an IRIS workstation. Mike indicated that there was an IRIS system in code 910 that could be utilized for MAS Level-1B processing. The facilities available with this system (e.g. tape drives, Internet connections) will be investigated.

MODIS AIRBORNE SIMULATOR (MAS)
LEVEL-1B PROCESSING SYSTEM SUMMARY

MODIS Science Data Support Team

June 21, 1991

MAS processing system summary

The following is intended as a guide to current knowledge of the requirements for the development of a MAS Level-1B processing system. At present it is envisioned that a facility will be developed at GSFC to take MAS Level-1A data, compute calibration and navigation parameters, and then supply a Level-1B dataset to users. Further processing of the Level-1B data would be done on the user's own system. It is also planned to develop an interactive browse system at GSFC which will allow users to review image data from a MAS flight mission to check cloudiness, land/ocean coverage, and coverage of areas of interest.

Subjects included in this summary are

(1) MAS Instrument details
(2) MAS Level-1B processing requirements
(3) Proposed sequence for MAS Level-1B data processing
(4) Considerations and questions for MAS Level-1B processing
(5) Schedule for MAS Level-1B processing system development

This summary is intended to be used as a guide only, and is subject to revision.

MAS instrument details

Precursor	: Daedalus WILDFIRE sensor
Spectral bands	: 50
Output channels	: 12 8-bit channels initially (can configure 4 10-bit and 7 8-bit channels) and may increase to 50 12-bit channels eventually
IFOV	: 2.5 mrad initially, may change to 5.0 mrad
Flight altitude	: 20 kilometers (ER-2 aircraft)
Ground resolution	: 50 meters at nadir for 2.5 mrad IFOV, 100 meters at nadir for 5.0 mrad IFOV
Total scan angle	: 85.92 degrees
Swath width	: 37 kilometers
Pixels per scan	: 716
Scan rate	: 6.25 scans per second (oversamples both cross track and along track)
Data rate	: 0.4296 megabits per second 193.32 megabytes per hour (for 12 8-bit channels, image data only)
Calibration	: Onboard blackbody targets for infrared bands. Pre and post flight ground-based integrating sphere for visible and near-infrared bands.

MAS Level-1B processing requirements

- The first MAS/WILDFIRE flight will occur in November 1991. The MAS Level-1B processing system should be in place by this time.

- The aim of the MAS Level-1B processing system should be to produce data with accurate calibration and navigation, in a format that is readily accessible to users.

- Calibration accuracy is of primary importance to all users. Some users may wish to retain calibration source information in the MAS Level-1B product.

- Navigation accuracy desired varies between users, however accuracy better than half a pixel may be required. Users may need to perform their own ground control point navigation corrections to achieve these accuracies. Users may wish to use in-situ data in conjunction with MAS data so accurate navigation is essential.

- Some users may wish to perform geometric image corrections, so aircraft roll, pitch, yaw and altitude data should be preserved in the MAS Level-1B dataset.

- Co-registration of the MAS spectral bands within a single pixel is of importance to some users. Whether this issue can be addressed in Level-1B processing remains to be determined.

- Accurate registration of images between flight tracks or flight missions is required by some users.

- MAS Level-1B processing will be performed at GSFC, on a platform to be decided. A possible option is a Silicon Graphics IRIS workstation. This would provide speed, imaging capability, and connectivity to other systems via Internet. Facilities must be available to ingest the Level-1A MAS data from the source format (9 track magnetic tape) and to distribute the Level-1B product in the desired format for users.

- Processed MAS Level-1B data should be readily available to users either by electronic network links or magnetic media. The exact format of these links and media remain to be determined.

- An interactive browse facility should exist to enable users to examine data from a flight in order to determine cloud cover and/or regions of interest. Users who are not able to access the browse facility interactively should be provided with equivalent hardcopy imagery.

- MAS data format will be the same as exists for the Multispectral Atmospheric Mapping Sensor (MAMS). Code to process MAMS data has been developed at the University of Wisconsin-Madison under the direction of Paul Menzel. The calibration and navigation portions of this code will be made available to facilitate development of the MAS Level-1B processing system at GSFC. It may be desirable to utilize the PC-MCIDAS facility at GSFC Severe Storms Branch to help develop and validate the MAS Level-1B processing system.

- Since the MAS will be an evolving system, with configuration changing from flight to flight, the MAS Level-1B processing should be able to handle changes in instrument configuration. This may involve the number of channels, the number of bits per channel, the spectral band assigned to a given channel, changes in spectral bands during flight etc. These changes are as yet unclear in definition.

Proposed sequence for MAS Level-1B data processing

(01) Level-0 data acquired by NASA ER-2 aircraft.
Format: Unknown (tape).
System: 12 channel digitizer, 8 bits per channel.
Center: Ames.

(02) Level-1A data generated by Ames Research Center (ARC).
Format: 9 track magnetic tape, 6250 bpi, fixed length binary records. Chris Moeller (Wisconsin) has information on record structure.
System: Unknown.
Center: Ames.

(03) Read Level-1A tape, write disk file.
Format: Direct access binary records (FORTRAN integer*2).
System: VAX or similar system with 9 track 6250 bpi tape drive and Internet connections.
Center: GSFC (for all subsequent steps).

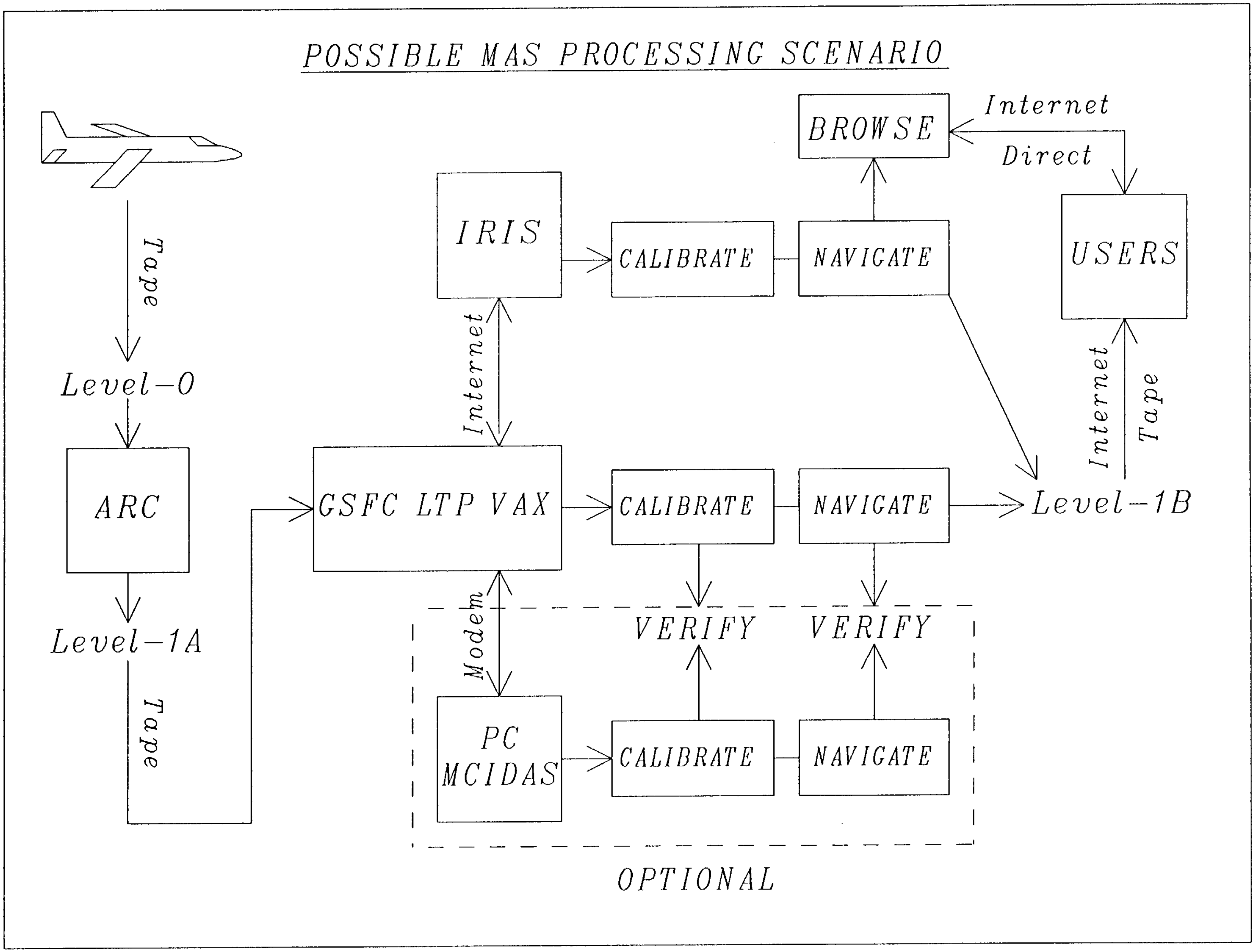
(04) Produce "quicklook" image for processing purposes only. Determine good data regions, check instrument information, check aircraft navigation information, determine dataset size, time, date and write to ASCII record file.
Format:
IMAGE - direct access binary records (FORTRAN integer*2).
ASCII - ASCII record of data/flight parameters containing summary information (fixed length 80 character records).
System: Silicon Graphics IRIS.

(05) Compute calibration slopes and intercepts and write to ASCII record file every 50 lines (or some specified number of lines).
Format: ASCII record file (fixed length 80 character records).
System: Silicon Graphics IRIS.

(06) Compute selected pixel locations using aircraft navigation data and write to binary file. Pixel locations can be computed subsequently by cubic spline interpolation.
Format: direct access binary records (FORTRAN integer*4)
System: Silicon Graphics IRIS.

(07) Generate browse imagery for flight sequence using selected spectral bands for cloud/feature identification.
Format: direct access binary records (FORTRAN integer*2).
System: Silicon Graphics IRIS.

(08) Copy image, flight record, calibration, navigation data to distribution system if necessary.
Format: Internet reachable node, or 9 track magnetic tape, 6250 bpi, fixed length records.
System: Silicon Graphics IRIS or VAX with Internet connection, and 9 track 6250 bpi tape drive.


POSSIBLE MAS PROCESSING SCENARIO
Tape
Level-0
ARC
Level-1A
Tape
IRIS
Internet
CALIBRATE
NAVIGATE
BROWSE
Internet
Direct
USERS
Internet
Tape
GSFC LTP VAX
CALIBRATE
NAVIGATE
Level-1B
Modem
VERIFY
VERIFY
PC
MCIDAS
CALIBRATE
NAVIGATE
OPTIONAL

Considerations and questions for MAS Level-1B processing

- Input data is in standard format on 9 track tape. However the input format may change in future. How can the changing instrument configuration and resulting data format be accommodated in the MAS Level-1B processing system?

- Does the data need to be converted to radiances in the Level-1B output, or just counts supplied with calibration slopes and intercepts?

- If the data is converted to radiance, should the data be supplied as band interleaved by line, or line interleaved by band?

- The Level-1B data will be used on a variety of systems, so portability must be maintained. Therefore the use of REAL data types is restricted. INTEGER data types are more portable.

- What accuracy should be retained for calibration and navigation data? INTEGER data types retain only limited precision.

- It may be desirable to provide navigation data at selected pixels only, and to then compute pixel locations by cubic spline interpolation. Users would then need to be supplied with a cubic spline interpolation routine.

- The format of the Level-1B output data needs to be decided. Should the data be supplied as real radiance values, or integer counts with calibration slope and intercept? Should the original blackbody counts be included with the data? Should the original aircraft INS (altitude, pitch, roll, yaw) data be included?

- Several calibration strategies are available for the MAS thermal infrared bands. A common method acceptable to all users must be decided upon.

Schedule for MAS Level-1B processing system development

June 1991

Complete initial studies of user requirements for MAS Level-1B data. Investigate hardware options available for processing.

July 1991

Obtain calibration and navigation software, and MAMS test data from Wisconsin. Start source code development on selected processing platform. Investigate imaging software available on processing platform. Investigate MAS Level-1B output data format options.

August 1991

Continue calibration and navigation code development, testing and documentation. Investigate browse strategies using selected imaging software. Produce initial imagery of MAMS test data. Finalize design of MAS Level-1B output data format.

September 1991

Continue calibration and navigation code development, testing and documentation. Start testing code against MAMS MCIDAS produced calibration and navigation data. Finalize strategy for browse system. Start implementation of browse system.

October 1991

Complete calibration and navigation code development, Version 1.0. Complete code documentation. Continue testing code with MAMS test data, and compare results to MAMS MCIDAS calibration and navigation. Produce calibration and navigation code user guides. Introduce processing system to users. Complete browse system development, Version 1.0. Complete browse system documentation. Introduce browse system to users.

November 1991

Set up processing system and browse system ready for first MAS/WILDFIRE flight during FIRE. Test processing and browse systems with MAS data as soon as it becomes available. Distribute MAS Level-1B data to users.

Comments Received from Dr. Robert Evans:
MODIS Level-1 Granule Size

June 19, 1991

To facilitate investigator research at the SCF and the TLCF, the MODIS Level-1A and Level-1B granule size should be chosen as large as possible, consistent with on-line storage limitations imposed by local processing facilities. Granule size plays a critical role at the point where the investigator begins to assemble required ancillary data sets from EOS and external sources. If the MODIS processing granule is small, the investigator must either process a large number of data requests for small chunks of ancillary data or abandon the idea that MODIS granules can be processed individually, and order ancillary data sets for multiple MODIS granules. Either way, the basic simplicity of the "processing granule" is lost and the acquisition of ancillary data sets is made unnecessarily complicated.

The experience base for the above assertions came from the CZCS. When the granule size for this project was chosen, the granule size was maximized based on the then-available on-line storage of representative processing facilities without allowance for the increase in storage capacity that would occur during the development time for the project. The result was granules that were too small, "disastrous" complexity in ancillary data acquisition, and continuing frustration among CZCS developers and system operators.

Experience at Miami indicates that a granule size of approximately 100 MB is appropriate for a total disk storage capacity of 5 GB. A full orbit of MODIS data would be too large; historically, navigation routines have also introduced anomalies at dateline transitions when processing orbit-based granules. Day and night transition boundaries (observation mode switch points) make a nice reference for granule definitions.

Although the "processing granule" should be large, investigators will need to access "subsetted" data products containing less than a full granule of data. For ocean R&D processing done at Miami, only certain bands of Level-1A data are needed, and a considerable reduction in data transmission volume can be realized by band selection and data compression techniques. Reductions to about 1/10 or 1/30 of original volume are thought to be possible. Similar reductions may be possible at the TLCF. Miami envisions the PGS at Goddard as the operational data production facility, Miami as the investigative or R&D site, and the TLCF as the primary instrument calibration and product validation site.

Comments Received from Dr. Stuart Biggar
Associate Team Member, Phil Slater's Land Calibration Team:
MODIS Level-1 Granule Size

June 17, 1991

The land calibration team will order MODIS Level-1A data, but only during a field campaign when an observation crew is in place to provide reference observations for the calibration site. This will occur infrequently; perhaps a hundred field campaigns will be conducted during the project lifetime (15 years). Since their needs are small, land calibration requirements should not drive the Level-1 system design.

Land calibration will actually use data from perhaps a 512 x 512 pixel area. Since data must be accessed electronically to meet timeliness requirements, the crew would prefer to receive a subsetted data block containing just the data they need. The University of Arizona presently has access to a T-1 telephone link.

Questions for Dr. Bill Barnes
(copy to Dr. John Barker)

June 20, 1991

Does the choice of Level-1 (or Level-2) product granule size affect MCST activities in any way? If so, what granule size would you prefer, and why?

MODIS Level-1 Granule Size

PRELIMINARY

June 21, 1991

<u>Definition of a Data Granule.</u> A MODIS data granule is the smallest unit of MODIS data that will be processed and stored within the EOSDIS. Depending on system needs, a single granule size may not be optimum for all system functions, and separate granule definitions may be given for the Processing Granule (the smallest unit of data that can be processed at a given level of MODIS processing), the Archive Granule (the smallest unit of MODIS data at a given level that is stored in the long-term archives), and the Distribution Granule (the smallest unit of data that can be distributed to a MODIS data user). It will initially be assumed here that these three granules are identical. If requirements to optimize processing, storage, or distribution force distinct granule definitions that depend on system function, such requirements will be noted in the discussion and included in the results of the granule size study.

<u>Processing Level Transitions.</u> Because of data transmission constraints between the platform and the ground receiving station, MODIS Level-0 packet length is limited to about 7,000 bits. A packet is the natural granule for Level-0 data. Granule sizes may be redefined at each successive level of MODIS processing, and in particular, MODIS Level-3 includes a variety of spatially and temporally averaged products that necessarily use multiple granules as input and do not stand in a one-to-one relation with their Level-1 or Level-2 inputs. MODIS Level-1 and Level-2 granule sizes need not match those of either Level-0 or Level-3. A possible granule flow is as indicated in Figure 1. The MODIS Science Team Members are responsible for Level-2 and -3 granule definitions; only factors affecting the definition of Level-1 granules are discussed in this document.

<u>Utility of Metadata.</u> Since metadata describing the contents of an individual granule will be generated for each granule, granule size may affect the utility of the metadata that the ultimate data user will use to select data that suits his purpose. A list of representative metadata items was included in an appendix to the latest EOSDIS specification (14 December 1990), and for reference, this list is included as an appendix to this document. The metadata needs of the science community must be defined by the science community itself, and additional discussions among Science Team Members will doubtlessly be required to complete the specification of metadata content and the granularity at which metadata is needed.

A Possible MODIS Granule Flow

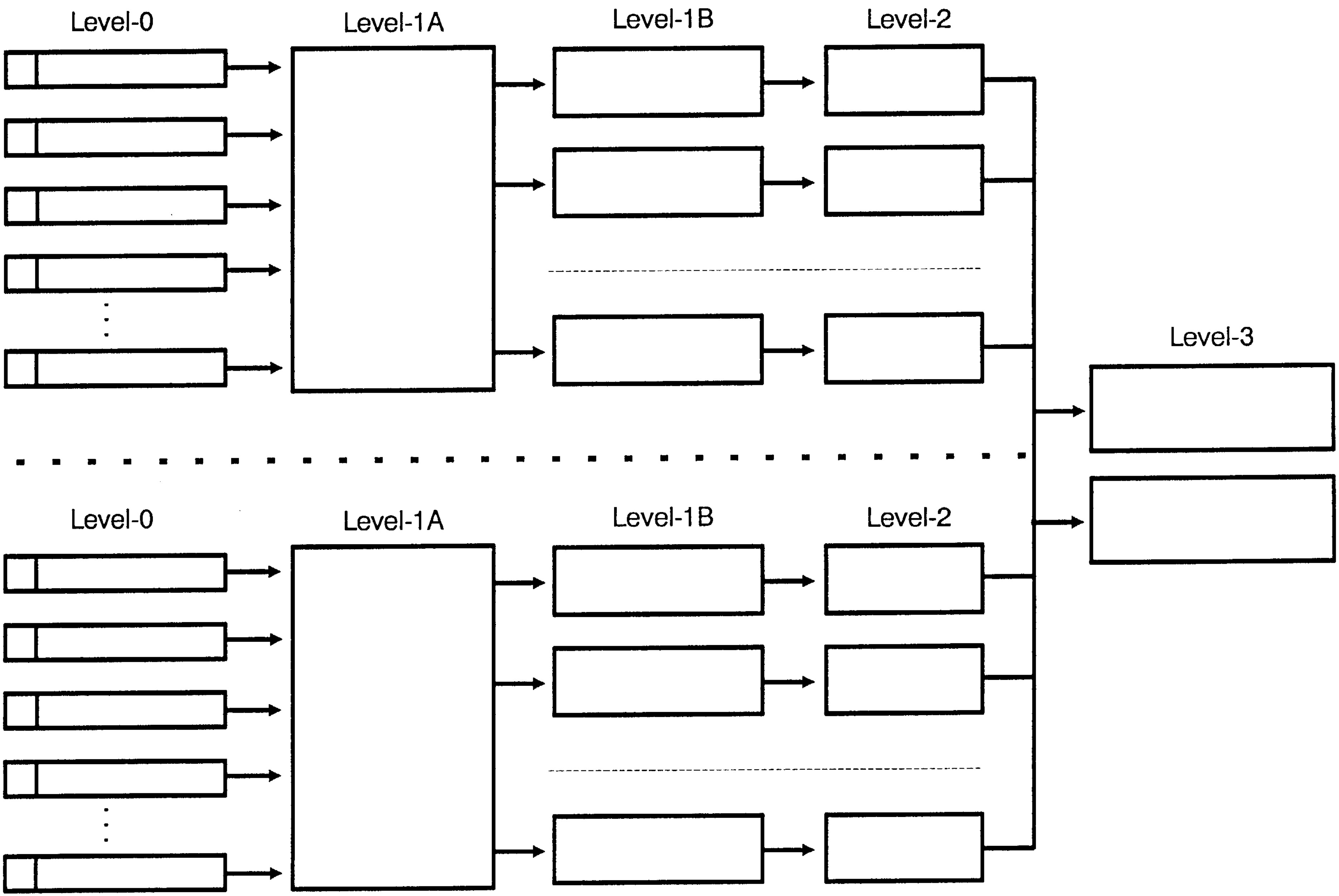


Table C-10: Baseline Core Meta Data Attributes

Fieldname	Bytes	Description
Algorithm Version Number	80	Version number & algorithm name
Archive ID	14	Archive location identifier
Coverage	100	Rect,circular, or elliptical coordinates
Data Type	10	Data type (ancillary, housekeeping,etc)
Footprint	2	Bounding shape (rect,elliptical,circ)
Geographic Location Keywords	20	Continent, ocean, or global location
Granule ID	16	Granule Identifier
Investigator	32	Investigator ID
Platform ID	10	Platform on which sensor was located
Processing Level	2	Level of processing
Product Sequence Number	10	Product identifier
Project ID	40	Supported project that collected the data
Sensor ID	10	Sensor which captured data
Start Orbit Number	4	Orbit number at start of data collection
Stop Orbit Number	4	Orbit number at end of data collection
Start Time	7	Date and time data collection started
Stop Time	7	Date and time data collection stopped
Total Bytes	368	

The Core Inventory Metadata Attributes are the minimum set of attributes necessary for an inventry entry.

Table C-11: Baseline Data Set Specific Meta Data Attributes

Fieldname	Bytes	Description
Attitude Information	42	Min & max yaw, pitch and roll
Band Quality	80	Indicator of band quality
Cloud Cover	20	Cloud cover by percentage
Data Gap	240	Includes orbit no.,Lat/Long, time span
Data Quality	20	Quality assessment of data granule
Day Night Flag	1	Indicates image obtained day or night
Ephemeris Information	80	
General Comments	240	General remarks
Image Description	80	General comments about image
Inventory Date	7	Date granule ingested into inventory
Land/Ocean Tag	20	Percentage land/ocean
Latitudional Resolution	6	Latitudinal gridding of the data
Longitudional Resolution	7	Longitudional gridding of the data
Max Geocorrected Latitude	6	Max latitude of the image after geocorrection
Max Geocorrected Longitude	7	Max longitude of the image after geocorrection
Max Satellite Zenith Angle	6	(-90.00 to 90.00)
Max Sun Azimuth	6	Max sun azimuth for the data
Max Sun Zenith	6	Maximum sun elevation above the horizon
Min Geocorrected Latitude	6	Min latitude of the image after geocorrection
Min Geocorrected Longitude	7	Min longitude of the image after geocorrection
Min Satellite Zenith Angle	6	(-90.00 to 90.00)
Min Sun Azimuth	6	Minimum sun azimuth for the data
Min Sun Zenith	6	Minimum sun elevation above the horizon
Number of Bands	4	Number of spectral bands
Number of Data Gaps	4	Number of missing lines in image
Number of Lines	4	Number of lines or scans in the data
Number of Observations	4	Number of observations included in data
Number of Samples	4	Number of samples or pixels in a line
Operation Mode	80	Description of operation mode
Parameter Information	400	Up to 20 parameters (20 bytes per parameter)
Processing Date	7	Date the product was processed
Processing Location	14	PGS where product processed
Scene ID	10	Input scene Identifier
Start Line From Original	4	Starting line from master scene, if subsetted
Start Pixel From Original	4	Starting pixel from master scene, if subsetted
Storage Medium	4	Storage media
Subset Flag	1	Indicates if the image subsetted from a master
Tilt Angle	5	
Total Data Set Specific	**1454**	
Total Core Metadata	**368**	
Total Inventory Record Size	**1822**	
Daily Granule Count	**21296**	**From Number of Granules Per Day Table**
Inventory Size Per Day (MB)	**74**	**Includes Reprocessing Factor of 2**
Inventory Size Per Year (GB)	**26**	
Mission Inventory Size (GB)	**390**	**15 year mission**

MODIS-T GRANULE SCENARIOS			
Duty cycle	45%		
Scan period (sec)	4.545		
Orbit period (min)	98.88		
Frames per daytime scan	1024		
Packets per daytime scan	2049		
Packets per nighttime scan	66		
Scans in daytime portion	587.4		
Scans in nighttime portion	717.9		
Integer daytime scans	588		
Integer nightime scans	718		
Integer scans in orbit	1306		
Packets per orbit	1,252,200		
Daytime scenes per orbit	11		
Nighttime scenes per orbit	1		
Total scenes per orbit	12		
Orbits per day	14.6		
Approx bytes per packet	1000		
GRANULARITY	Number of Granules/Day	Granule Volume (mbytes)	Daily Metadata Volume (mbytes)
1 granule per day	1.0	17,890	0.002
1 granule per orbit	14.6	1,229	0.027
1 granule per scene	160.2	61	0.531
1 granule per scan	19,008.0	1	34.63
1 granule per packet	18,235,163	0.001	33,224

ONE POSSIBLE MODIS LEVEL-1B (AND LEVEL-2) SCENE CONCEPT

DESCRIPTION OF THE CONCEPT OF THE MODIS STANDARD SCENE:

- The concept is applicable for the purposes of archival, browse, and computing metadata.
- Each orbit is divided into 20 approximately equal-length segments (approximately five minutes), termed "scenes"; the scenes have approximately square dimensions.
- Nighttime scenes are deleted, except for a single "scene" (granule) containing all nighttime mode data.
- MODIS day/night mode changes define the nighttime edge of the scenes near the terminators.
- The segments are defined based on the sub-satellite point (SSP) position.
- The first scene for each orbit (and day) begins with the first scan after the descending node.
- Each scene extends across approximately 18° of along-track angle (to within the closest scan boundary).
- Due to 1:30 PM ascending node (terminator is not normal to orbit) and need for BRDF model development over poles, the 45% duty cycle needs to be examined further

ADVANTAGES OF THE STANDARD SCENE CONCEPT:

- Convenient, approximately equal along-track/across-track dimensions.
- Scene definition is the same in terms of sub-satellite point for MODIS-N and MODIS-T.
- Scene boundary = orbit boundary = day boundary; scenes are standard in Earth latitude.
- The data are partitioned into manageable groups (20 per orbit).
- Data may be addressed by scene and orbit number (either absolute or within 233-orbit repeat period).
- Data may be accessed by latitude, longitude, and date.

DISADVANTAGES OF THE STANDARD SCENE CONCEPT:

- More granules to account for than if the granularity is per orbit.
- More data to be handled if the interest is for less than 5 minutes of data.
- When MODIS-T tilts, relative along-track displacement of -N and -T scenes occurs.
- Scenes containing the terminator may require special handling.
- The size of the scene is arbitrary.

ONE POSSIBLE MODIS LEVEL-1B (AND LEVEL-2) SCENE CONCEPT												
Orbit Number	Scene Number	Start Orbit Angle	End Orbit Angle	Ascending/ Descending Node	Start Latitude	End Latitude	Along-Track Length	Duration (minutes)	Start Time (minutes)	End Time (minutes)	Day/Night Status	Number of Scans (MODIS-T)
1	20	18	0	D	17.8	0.0	2000	4.9	93.9	98.9	Night	65
2	1	0	-18	D	0.0	-17.8	2000	4.9	0	4.9	Night	65
2	2	-18	-36	D	-17.8	-35.6	2000	4.9	4.9	9.9	Night	65
2	3	-36	-54	D	-35.6	-53.2	2000	4.9	9.9	14.8	Night	65
2	4	-54	-72	D	-53.2	-70.3	2000	4.9	14.8	19.8	Night/Day	65
2	5	-72	-90	D	-70.3	-81.8	2000	4.9	19.8	24.7	Night/Day	65
2	6	-90	-72	A	-81.8	-70.3	2000	4.9	24.7	29.7	Day/Night	65
2	7	-72	-54	A	-70.3	-53.2	2000	4.9	29.7	34.6	Day/Night	65
2	8	-54	-36	A	-53.2	-35.6	2000	4.9	34.6	39.5	Day	65
2	9	-36	-18	A	-35.6	-17.8	2000	4.9	39.5	44.5	Day	65
2	10	-18	0	A	-17.8	0.0	2000	4.9	44.5	49.4	Day	65
2	11	0	18	A	0.0	17.8	2000	4.9	49.4	54.4	Day	65
2	12	18	36	A	17.8	35.6	2000	4.9	54.4	59.3	Day	65
2	13	36	54	A	35.6	53.2	2000	4.9	59.3	64.3	Day	65
2	14	54	72	A	53.2	70.3	2000	4.9	64.3	69.2	Day/Night	65
2	15	72	90	A	70.3	81.8	2000	4.9	69.2	74.2	Day/Night	65
2	16	90	72	D	81.8	70.3	2000	4.9	74.2	79.1	Night/Day	65
2	17	72	54	D	70.3	53.2	2000	4.9	79.1	84.0	Night/Day	65
2	18	54	36	D	53.2	35.6	2000	4.9	84.0	89.0	Night	65
2	19	36	18	D	35.6	17.8	2000	4.9	89.0	93.9	Night	65
2	20	18	0	D	17.8	0.0	2000	4.9	93.9	98.9	Night	65

Note: Nighttime scenes and some day/night and night/day (depending on season) scenes will not be generated.

SPECIFICS OF GRANULE DEFINITIONS

Day boundaries are based on Greenwich time as 00 GMT. The MODIS data are segmented at the scan boundary closest to 00 GMT.

Orbit boundaries are based on descending nodes. MODIS data are segmented at the scan boundary closest to the equator.

Daytime granules are based on MODIS scenes each about 5% of an orbit and 2,000 km in length. These granules are broken at the day boundary and begin/end at the off-on/on-off MODIS mode changes.

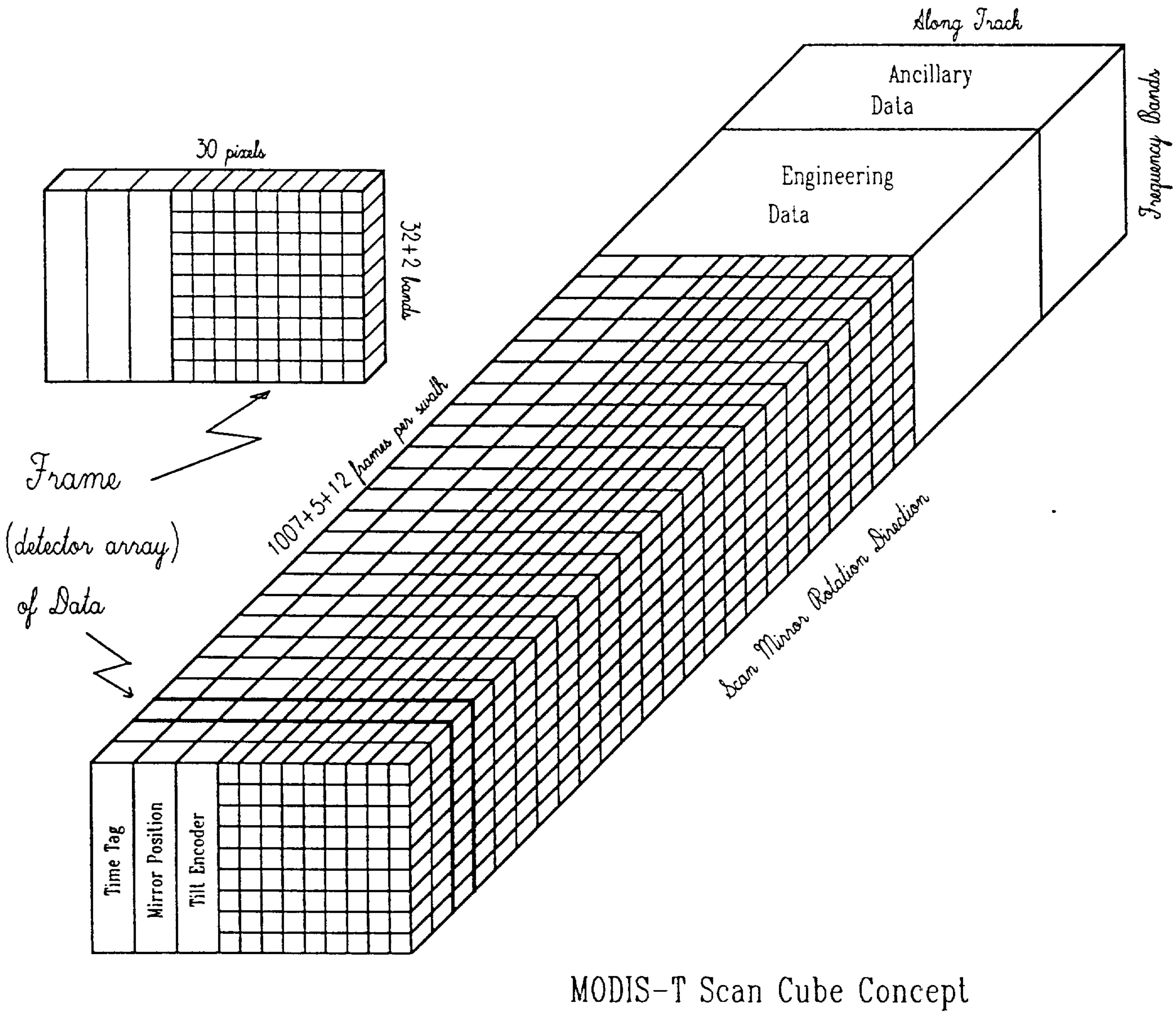
With MODIS-T having a 45% duty cycle (50% is probably more realistic due to lunar calibration and polar BRDF studies), 9 to 11 daytime granules per orbit are created, with one more for those orbits containing a day boundary. 1 or 2 nighttime granules can be created per orbit.

Through this procedure, data are partitioned realistically into the days they belong. Second, the truncation of scenes when MODIS is turned on or off saves storage space. Third, the low nighttime engineering data rate permits the nighttime data to be consolidated. And finally, this scheme handles consistently day boundaries, orbit boundaries, scene boundaries, and the on-off duty cycle for the MODIS instrument.

Executive Information Summary
of the
MODIS Level-1A and 1B
Data Products

The various levels in the MODIS chain of processes create data products consisting of the MODIS data product and an accompanying metadata. This document summarizes the contents of these Level-1A and Level-1B data products.

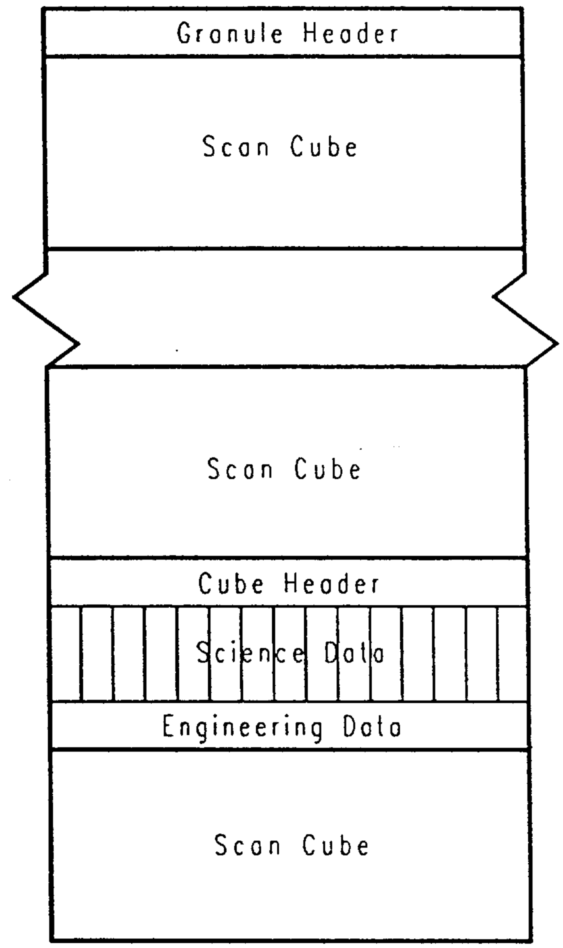
<u>MODIS Level-1A Data Product</u>. The Level-0 Data Product consists of the instrument data in packetized form as received from CDOS. Packets are directed by CDOS to the MODIS processing program via the DADS. They consist of the MODIS instrument packets and the spacecraft ancillary data packets containing position and attitude information. These are the only data required for MODIS Level-1A processing. The packets of data are placed into computer memory which is represented as scan cubes



MODIS-T Scan Cube Concept

contained within a data product granule. These concepts are illustrated in the accompanying diagrams. For example, the MODIS-T daylight scan cube contains frames of data composed of the pixel data from one readout of the solid state detector array, plus tilt angle, scan mirror angular position, and a time tag. Successive readouts of the detector array occur as the scan mirror rotates. Included in each swath are the engineering house keeping data and instrument ancillary data. The spacecraft position and attitude data are contained within this ancillary data but are not applied to the data.

The scan cubes of data are placed into the data granule structure in a time ordered fashion. The data granule for the Level-1A product is expected to be an entire orbit's worth of data. Appended to this data granule will be a granule header. A separate data product consisting of the MODIS metadata will be included. This Level-1A data will not be unpacked (13 bits into 16 bits) or altered in any way. This is the raw instrument data with nothing other than duplicate packets removed.



Granule Structure

Level-1B Data Product. At satellite radiances are provided in the Level-1B Data Product. These radiances will be calibrated using a concensus algorithm. Ground location at selected anchor points will be appended to the data product using the WGS84 ellipsoidal Earth model. This does not include a digital elevation model (DEM). No correction for atmospheric effects will be included or applied to the radiance values. No ground looking data (control points or in-situ) will be used in either the calibration or the anchor point determination. No scene characterization flags (cloud, land, ocean, etc) will be included in the Level-1B data product. Metadata from Level-1A will be upgraded and appended to produce the Level-1B metadata.

A given version of the Level-1B Data Product is derived only from the information contained within the Level-1A data product. Calibration algorithms and coefficients, earth location criteria, or platform position and attitude will not be altered without forcing a revision change to the software and data product.

General Considerations. The MODIS processes will not inform other processes or projects of problems or anomalies detected from the MODIS telemetry data. The modis Processing Log will contain these items.

All MODIS processors will handle all MODIS instrument and product modes with only one set of software. There will not be a separate program for quick_look or reprocessing modes.

All MODIS processing algorithms and code will be freely available to interested parties.

MODIS Level-1 Processing Assumptions

compiled by the
MODIS Science Data Support Team
20 June, 1991

This list of assumptions is associated with the design of the MODIS Level-1 data processing. The assumptions may change as comments are received, and as refinements are made to the Level-1 processing system design. The numbering of items comes from a master list being tracked by the MODIS Science Data Support Team. Only those items which may be of interest to MODIS Science Team members are included in this abbreviated list.

Unpacking Data (016). MODIS data will not be unpacked (byte aligned) at Level-1A.

Leaving the data in a packed form minimizes the size of the data set in the absence of data compression. It also minimizes the time and complexity of Level-1A processing. Unpacking the data at Level-1A could increase the probability of error in the lowest level of permanently archived data.

Level-1A Navigation (017). Earth locations of MODIS pixels will not be determined at Level-1A.

This function is contained in the Level-1B process.

Required Ancillary Data (042). All data required for MODIS Level-1B processing will be included in the MODIS Level-1A product.

The data product is defined to include its associated metadata. This assumption says that all data required to process to the Level-1B product (including metadata) will be contained within the Level-1A data product. This means that no in-situ data is required, and that no auxiliary data sets are required (i.e. other instrument motions causing momentum effects, platform thermal deformation data not in the MODIS packets, previous MODIS data products, etc.). See also: Engineering Data.

Platform Position and Attitude Knowledge (037). MODIS Level-1B processing will use the satellite position and attitude knowledge supplied by the EOS project and appended to the Level-1A data.

This assumption implies that the MODIS process will not be executed before the spacecraft position and attitude are known. If the spacecraft position or attitude are updated after the MODIS data product has been generated, a MODIS reprocessing may have to be initiated by an outside authority. The current MODIS design appends the satellite position and attitude to the Level-1A data product. This can lead to a lack of concurrence (more than one version of a data set) with the attendant danger of not having the current, most accurate data.

Position and Attitude Knowledge for Quick-Look (052). MODIS Quick-Look processing will use the best available satellite position and attitude data.

For the Quick-Look mode, the best available position and attitude will be used with appropriate quality indicators. This may consist of data derived from orbital predictions or other similar methods.

Orbit and Attitude Correction (022). The process of updating instrument position and attitude information already appended to Level-1A data will be performed in a separate utility process.

The current design of the MODIS process simply appends the spacecraft platform position and attitude data to the Level-1A data product. Thus a utility program can 'patch' the platform data with newer or more correct values without reprocessing the Level-1A instrument data. The data product must contain the version number of the platform position and attitude data in addition to the processing version number to provide a means of checking for inconsistencies. Products based upon a given Level-1A product that has been updated might need to be reprocessed and would require a backwards pointer to the data source with the appropriate database links.

Coordinate System (031). Coordinates will be represented in the geodetic latitude-longitude coordinate system on a standard ellipsoid.

Coordinate transformations from the EOS platform coordinate system to the ground based geodetic latitude-longitude coordinate system will be performed by the MODIS process using standardized transformation routines. Latitude will be given in the geodetic coordinate system.

Anchor Point Selection (032). For each scan, a set of anchor points will be selected for interpolating the ground locations of pixels within the scan.

See the report "An Analysis of MODIS Anchor Point Accuracies for Earth Location", MODIS Data Study Team, Revised: April 5, 1991 for details of the anchor point method. The ground locations of the selected pixels are determined solely from the satellite position, attitude, and instrument geometry without the use of ground (in-situ) control points.

Anchor Point Parameters (033). The following parameters will be provided in the Level-1B data set for each anchor point: earth location (geodetic latitude-longitude) of the pixel, satellite slant range, satellite azimuth and zenith angles, and solar azimuth and zenith angles (all with respect to the pixel).

The zenith angles are relative to the normal to the local geodetic surface at the pixel. Other needed parameters such as solar to spacecraft relative azimuth can easily be calculated from the appended parameters. The slant range facilitates the computation of any digital elevation model (DEM) corrections in later processes.

Anchor Point Error Statistics (034). No measure of earth location accuracies will be included in the Level-1B data product.

An indication of anchor point statistical accuracies can be derived externally in a non time critical environment. The accuracies are not unique to an individual data product. Accuracies are to be derived from platform knowledge parameters initially and verified via off-line methods to be available after the MODIS data has been disseminated.

Feature Identification (035). No Feature Identification/Ground Control Points will be used at Level-1B for earth location.

No in-situ data, derived either from ground feature selection or a-priori positioning, will be required to produce the Level-1B data product.

Land/Ocean Flags at Level-1A (024). Land/Ocean, Cloud, or other derived flags will not be included in the Level-1A data product.

The scan data is in uncalibrated digital (raw) count form thereby precluding the use of any cloud detection algorithm at Level-1A.

Land/Ocean Level-1A Products (025). The Level-1A product will be supplied without separation into land/ocean or other categories.

Navigation is not performed in the Level-1A process. Therefore, earth referencing information is not available to allow a land/ocean flag to be generated.

Level-1B Land/Ocean Flags (039). Land/Ocean flags will not be included in the Level-1B data product.

The current Level-1B design contains no provision for data flags. Generating a land/ocean flag would require a Team Member agreed upon coast line database.

Level-1B Cloud Flags (051). Cloud flags will not be included in the Level-1B data product.

Cloud flag determination would require a definitive cloud detection algorithm or means for a multi-valued flag. Cloud algorithms are expected to be derived from MODIS-N data and possibly applied to MODIS-T data. This would require registration of the two MODIS products during the Level-1B product generation.

Land/Ocean Level-1B Products (040). The Level-1B product will be supplied without separation into land/ocean or other categories.

Level-1B MODIS data products are not categorized by spatial parameters when transferred to the archive although the headers and Metadata contain statistics and indicators for this characterization. Data product splitting is a DADS function.

Level-1B Elevation Correction (036). There will be no terrain elevation correction (beyond the reference ellipsoid) to earth location at Level-1B.

Any use of a Digital Elevation Model (DEM) will be performed in follow-on processing upon the determination of a DEM procedure and appropriate model.

Atmospheric Correction (038). No atmospheric correction of any kind will be applied to the MODIS level-1B data.

The definition of MODIS Level-1B data is at-satellite radiances, uncorrected for atmospheric effects such as absorptive, scattering, and refraction.

Level-1A Browse (026). There will be no Level-1A browse product.

Browse data derived from raw instrument counts with no earth referencing would be of very limited use. Browse data requirements will be generated by the MODIS Science Team Members.

Level-1B Browse (041). The Level-1B process will not generate browse products.

Any required browse products will be generated by a separate browse process in order to take advantage of future technology advances without compromising the main data product processing. This allows technologies such as those currently in development for high definition television (HDTV), windowed graphical user interface (GUI), laser based video, or similar approaches to be used as they are developed without changing the basic Level-1B product generation function. This also allows for the concept of 'on the fly' or demand browse to be implemented.

Calibration (043). Calibration algorithms and parameter values will be provided by the MCST.

Both algorithms and parameters (coefficients) will be incorporated into the Level-1B software by the SDST. Any change of algorithms or parameters will force a Configuration Management revision update. A full validation will be performed to detect overflow, underflow, error trapping, variable availability, etc.

Engineering Data (044). MODIS Level-1B processing will extract instrument engineering values from each Level-1A scan cube individually.

All of the instrument engineering values needed for calibration will be included in the Level-1A data product. No external data source will be required. All values required to perform a calibration of pixels within a scan cube will be contained within that same scan cube. Previous or future scan cube data will not be required to calibrate the current scan cube. If calibration requires a differing approach, the current design will require modification.

(Clarification/modification of this assumption is to be provided by the MCST)

QUESTIONS AND ISSUES:

Cloud/No-Cloud (009). At which processing level will the cloud/no-cloud flag come into the system? Who determines if a cloud flag is desirable? Which algorithm is used to determine the presence of a cloud? Is it derived only from MODIS data or some other instrument that must be spatially co-located with MODIS?

A Cloud/No Cloud flag will be part of the Level-2 product. Every pixel will be flagged (John Barker).

Quality Checks (010). Who will provide a list of quality checks to be applied in the Level-1A and Level-1B processing? This includes product quality assurance (missing data, temporal characteristics, etc) and data quality (coherent noise, saturation, etc).

The MCST will provide an integrated set of quality checks from all sources, including team members. The MCST will also provide a list of error messages to be generated when the data fail to pass the quality checks.

6/10/91

October 1, 1990

TO: Distribution
FROM: 725.3/Systems Engineering Section
SUBJECT: Data Packets for MODIS-T

This memo provides top level recommendations for four types of data packets for MODIS-T. The instrument manager and I developed this list. Details on how packets are configured may be found in the Consultative Committee for Space Data Systems (CCSDS) documents referenced in the General Instrument Interface Specification (GIIS).

1. Normal Data: This packet has science data, calibration data, and some engineering data. It includes half a frame of scan data or 6928 bits. These bits are 13 bits per pixel times 34 bands times 15 IFOV in the scan direction = 6630 bits (the readout from one half of the detector array) plus 298 bits for time, orientation, and voltages and currents.

Normal scan data is collected on the sun side of the orbit. On occasion, this type of packet could be collected on the dark side of the orbit.

During one scan of the Earth (one swath), 1007 frames of ground data, 5 dark frames, and 12 calibration frames are collected. The packet format would be the same for all this data, since the calibration and dark frames would use the same detector as the ground scene. Since each packet has data for one half of the detector, a particular pixel would appear in every other packet.

2. Swath End: This packet is collected at the end of each swath of data and consists of the following: electronic reference (2400 bits), thermistors (384 bits), platform position (96 bits), time tag (64bits), and instrument status (200 bits). Additional bits would be added for contingency to bring this packet to a desired size.

3. Night Data: This packet is collected normally during the dark portion of each orbit. For each frame, the 298 bits of time, orientation, and voltages and currents would be collected. A swath would include 1024 frames of 298 bits each, plus the 17 calibratioin frames of 13,260 bits each. The electronic reference, thermistors, POP position, time tag, instrument

status, and packet header would bring the total bits per swath to 537,345 for night data.

4. Diagnostic Data: This packet would be used only in a diagnostic mode. The header would include normal data, plus the type of diagnostic data, plus the number of data values. The size could be fixed, if convenient at about the normal packet size.

Mike Roberto
MODIS-T Systems Engineer

Distribution: Tom Magner/721
Doug Ross/728

6/10/91

	A	B	C	D	E	F	
1	Revised on		6/10/91				
2							
3							
4		Num.	Day	Night		Health/Safe	
5	Ground Frames		1007	16			
6	Dark frames		5	5			
7	calibration frames		12	12			
8	**total frames**		**1024**	**33**		1	
9							
10	**#bits/frame**						
11	frame(12 bit A/D plus gain bit)		13260	13260		13260	
12	tilt		18	18		18	
13	scan		18	18		18	
14	time tag		64	64		64	
15	**Total Bits per Frame**		13360	13360		13360	
16							
17	**bits/swath**						
18	frames (total frames * total bits/frame)		13680640	440880		13360	
19	electronic reference (30*13 bits):		390	390		390	
20	**thermistors (48*8 bits each)**	48					
21	PDU	4	32	bits 32		32	
22	C&DH (Side which is on)	4	32	32		32	
23	Drive Box	4	32	32		32	
24	Detector Drive Box	4	32	32		32	
25	Thermal Box	2	16	16		16	
26	Detector Power Supply	4	32	32		32	
27	Signal Processing Box	4	32	32		32	
28	Mechanisms (2 ea for the four mechanisms)	8	64	64		64	
29	Calibration Spheres	4	32	32		32	
30	PMP	2	16	16		16	
31	Optical Bench	8	64	64		64	
32	Photo-diode Calibration(4*12 bits)		48	48			
33	Diffuser Encoder		4	4		48	Jump one
34	Aperture Encoder		8	8		4	
35	**Relay Positions (256 * 1 bit each):**	256				8	
36	Misc.	32					
37	PDU	32	32	32			
38	Mechanism Drive	32	32	32		32	
39	C&DH (Side which is on)	32	32	32		32	
40	Thermal Box(32)	32	32	32		32	
41	Detector Drive Box(32)	32	32	32		32	
42	Analog Processing Box(32)	32	32	32		32	
43	Detector Power Supply(32)	32	32	32		32	
44	**Voltages/Currents(96 - 8 bit):**	96					
45	PDU	16	128	128		128	
46	C&DH	16	128	128		128	
47	Mechanism Drive Electronics	16	128	128		128	
48	Detector Drive Electronics	16	128	128		128	
49	Analog Processing Electronics	16	128	128		128	
50	Thermal Electronics	16	128	128		128	
51							
52	Total Bits/Swath (before header):		13682466	441938		64	
53	Packet Header (0.68%)		93041	3005	no packets	15218	
54	**Total Bits per Swath**		13775507	444943		0	Jump one
55						15218	
56	Scan Mirror Speed (REV/Min)		6.6	6.6			
57	**Total Scan Time (sec)**		4.545	4.545	every 3 scans	6.6	
58						13.636	
59	**Transmitted Data Rate (Bits/sec)**		3030611	97887			
60						1116	
61	Orbit Data Rate		day-40% 45	night-60% 55			
62	**Average Orbit Data Rate**		1270977			1116	
63							